DESCRIPTION

POLYTRIMETHYLENE TEREPHTHALATE HOLLOW COMPOSITE STAPLE FIBERS AND PROCESS FOR PRODUCING SAME

FIELD OF THE INVENTION

The present invention relates to polytrimethylene terephthalate hollow composite staple fibers and a process for producing the same. Particularly, the present invention relates to polytrimethylene terephthalate hollow composite staple fibers having a latent crimping property, and a process for producing the same with a high efficiency. The polytrimethylene terephthalate hollow composite staple fibers of the present invention are useful for nonwoven fabrics, woven and knitted fabrics and cushioning materials having a high bulkiness and an excellent elastic recovery.

BACKGROUND ART

Polytrimethylene terephthalate fibers have excellent dimensional stability, light resistance, and heat-setting properties and low water- and moisture-absorption properties which are normal for polyester fibers and, further, they exhibit a low elastic modulus and an excellent elastic recovery and easy dyeability. Therefore, the polytrimethylene terephthalate fibers are expected to be developed as fibers for clothes and for industrial use.

It is well-known that composite fibers, in which two polyester components different in intrinsic viscosity from each other are conjugated with each other, and which have a latent crimping property, are utilized to provide woven or knitted fabrics or nonwoven fabrics having a high stretchability. To realize the polyester composite fibers having a latent crimping property, various attempts for, for example, increasing, as much as possible, the difference in the intrinsic viscosity of the two different types of polyesters, to increase the

difference in shrinkage between the two types polyester components in the resultant composite fibers and for enhancing the melt-spinning property of the polyester polymers, have been made. For example, Japanese Examined Patent Publication No. 61-60163 (1986) discloses a spinneret for melt-spinning two types of polyester resins different in melt viscosity from each other through a pair of melt-extruding orifices to form a side-by-side type composite filament. In this spinneret, an angle of inclination of each of the pair of melt-extruding orifices from a direction rectangular to the melt-extrusion face of the spinneret and the distance between the pair of melt-extruding orifices are specifically adjusted. Also, Japanese Unexamined Patent Publication No. 2000-239927 discloses polyester side-by-side type composite fibers in which in the cross-sectional profile of each composite fiber, two different types of polyester polymers are connected with each other in a specifically defined form.

It has been found, however, that when the difference in the intrinsic viscosity between the two types of polyester components in the composite fiber is increased to enhance the latent crimping property of the resultant composite fiber, the composite filamentary polymer melt streams extruded in the melt-spinning procedure bend, the degree of bending of the composite filamentary streams significantly increases with increase in the difference in the intrinsic viscosity between the two polyester components and, as a result, the bent composite streams adhere to adjacent streams or to the spinneret and are broken. Therefore, the melt-spinning procedure cannot be stably carried out. Further, as the polytrimethylene terephthalate composite filaments exhibit a lower rigidity than that of conventional polyethylene terephthalate composite filaments, when the latent crimps of the composite fibers are realized, a plurality of small crimps are created on the composite filaments and

thus the resultant crimped composite filaments difficult to exhibit a satisfactory bulkiness.

Still further, WO 02/31241-A1 discloses spun yarn containing composite fibers comprising two types of polytrimethylene terephthalate resins different in intrinsic viscosity from each other. The composite fibers have, however, an insufficient bulkiness and thus are not suitable for bulky nonwoven fabrics and cushioning materials.

DISCLOSURE OF THE INVENTION

An object of the present invention is to provide polytrimethylene terephthalate hollow composite staple fibers which have excellent bulkiness and elastic recovery and one appropriate for forming therefrom nonwoven fabrics, bulky yarns, bulky woven and knitted fabrics and cushioning materials, and a process for producing the same.

The inventors of the present invention have carried out extensive searches for attaining the above-mentioned object and found that the hollow composite stable fibers comprising two types of polytrimethylene terephthalate polymers different in intrinsic viscosity from each other and each having an intrinsic viscosity in a specific range, and provided with a hollow cross-sectional profile and a staple fiber form, enable the above-mentioned object to be attained. The present invention has been completed on the basis of this finding.

The polytrimethylene terephthalate hollow composite staple fibers of the present invention each comprise two parts which are constituted from polytrimethylene terephthalate resin components different in intrinsic viscosity from each other, arranged in a side-by-side or core-in-sheath arrangement, and extending along the longitudinal axis of each composite staple fiber, and having a hollow part formed within each composite staple fiber and extending along the longitudinal axis of each composite staple fiber,

wherein,

(1) one of the two polytrimethylene terephthalate resin components has an intrinsic viscosity in the range of from 0.50 to 1.40 dl/g, and the other one of the two polytrimethylene terephthalate resin components has an intrinsic viscosity in the range of from 0.40 to 1.30 dl/g, and 0.1 to 0.5 dl/g below that of the polytrimethylene terephthalate resin having the intrinsic viscosity of 0.50 to 1.40 dl/g, the intrinsic viscosities being determined in o-chlorophenol at a temperature of 35°C;

(2) the cross-section of the hollow part has a cross-sectional area corresponding to 2 to 15% of the total cross-sectional area of the composite fiber; and

(3) the composite staple fibers exhibit an average web area thermal shrinkage of 30 to 70% determined by such a measurement that the composite staple fibers having a fiber length of 51 mm are formed into a web having a basis mass of 30 g/m^2 by a roller carding machine, a plurality of specimens having dimensions of 20 cm × 20 cm are prepared from the web, the specimens are heat-treated in a hot air circulation dryer at a temperature of 120°C for 10 minutes, to allow the specimens to freely shrink and the web area thermal shrinkages of the specimens are determined in accordance with the equation (1):

$$\text{Web area thermal shrinkage (\%)} = [(A - B)/A] \times 100 \qquad (1)$$

wherein A represents of an area of each specimen before the heat-treatment and B represents an area of the specimen after the heat treatment, and an average of the resultant web area thermal shrinkages of the specimens is calculated.

In the polytrimethylene terephthalate hollow composite staple fibers of the present invention, the hollow part is preferably located in one of the high and

low intrinsic viscosity polytrimethylene terephthalate resin parts of each composite staple fiber.

The process of the present invention for producing polytrimethylene terephthalate hollow composite staple fibers as defined above comprises the steps of:

melt-spinning two polytrimethylene terephthalate resins different in intrinsic viscosity from each other through a hollow side-by-side or core-in-sheath type composite filament-forming spinneret, to provide undrawn hollow composite filaments;

drawing, in two stages, the undrawn hollow composite filaments at a total draw ratio corresponding to 60 to 80% of the ultimate elongation of the undrawn hollow composite filament, in such a manner that the drawing temperature is 45 to 60°C at the first stage and then 85 to 120°C at the second stage and the drawing ratio for the second stage is controlled to 0.90 to 1.0 so as to adjust the total draw ratio to the value mentioned above;

machine-crimping the drawn hollow composite filaments at a temperature of 50 to 80°C;

heat-treating the crimped hollow composite filaments at a temperature of 80°C or less while allowing the crimped hollow composite filament to relax; and

cutting the heat-treated hollow composite filaments to provide hollow composite staple fibers.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a cross-sectional profile of an example of the polytrimethylene terephthalate hollow composite staple fibers of the present invention having a side-by-side structure,

Fig. 2 shows a cross-sectional profile of another example of the polytrimethylene terephthalate hollow composite staple fibers of the present invention having a side-by-side structure,

Fig. 3 shows a cross-sectional profile of an example of the polytrimethylene terephthalate hollow composite

staple fibers of the present invention having an eccentric core-in-sheath structure, and

Fig. 4 shows a cross-sectional profile of another example of the polytrimethylene terephthalate hollow composite staple fibers of the present invention having an eccentric core-in-sheath structure.

BEST MODE OF CARRYING OUT THE INVENTION

The polytrimethylene terephthalate hollow composite staple fibers of the present invention each comprise two filamentary parts which are constituted from polytrimethylene terephthalate resin components different in intrinsic viscosity from each other, arranged in a side-by-side or core-in-sheath arrangement, and extending along the longitudinal axis of each composite staple fiber, and having a hollow part formed within each composite staple fiber and extending along the longitudinal axis of each composite staple fiber.

The polymethylene terephthalate is a polyester having, as principal repeating units, trimethylene terephthalate units. The trimethylene terephthalate resin usable for the present invention optionally contains comonomeric components. The comonomeric components include comonomeric dicarboxylic acids, for example, isophthalic acid, succinic acid, adipic acid, 2,6-naphthalene dicarboxylic acid and metal-sulfoisophthalic acid and comonomeric diol, for example, 1,4-butane diol, 1,6-hexane diol, cyclohexane diol and cyclohexane dimethyl alcohol. The comonomeric compounds are selected established in consideration of stability of the resultant copolymers in the melt-spinning procedure.

The polytrimethylene terephthalate resin optionally further contains an additive comprising at least one member selected from delustering agents, thermal stabilizers, anti-foaming agents, color-regulating agents, flame-retardants, anti-oxidants, ultraviolet ray-absorbers, infrared ray-absorbers, fluorescent brightening agents, and coloring pigments.

With respect to the two polytrimethylene terephthalate resin components different in intrinsic viscosity from each other, the intrinsic viscosity of each resin component is determined in a solution of the resin component in o-chlorophenol at a temperature of 35°C. The high viscosity resin component must have an intrinsic viscosity of 0.5 to 1.4 dl/g, preferably 0.8 to 1.30 dl/g.

If the intrinsic viscosity is more than 1.4 dl/g, the resultant high viscosity resin component exhibits an extremely high viscosity when it is melted in the melt-spinning procedure and thus cannot be melt-spun in an usual melt-spinning apparatus for polyester fibers, and to obtain a decreased melt viscosity at which the resultant polymer melt can be smoothly melt-spun, the melting temperature of the resin component must be increased to 280°C or more, at which temperature the resin component becomes decomposed. If the intrinsic viscosity is less than 0.5 dl/g, the difference in intrinsic viscosity between the resultant high viscosity resin component and the low viscosity resin component becomes too small and thus the resultant composite stable fibers cannot exhibit a sufficient latent crimping property.

The low viscosity resin component must have an intrinsic viscosity of 0.4 to 1.30 dl/g preferably 0.5 to 1.0 dl/g. If the intrinsic viscosity is less than 0.4 dl/g, the resultant resin component exhibit too low a viscosity in the melt-spinning procedure, and the resultant low viscosity melt causes the extruded filamentary melt streams to be frequently broken and the target composite filaments cannot be produced with a sufficient process stability. Also, if the intrinsic viscosity is more than 1.30 dl/g, the different in intrinsic viscosity between the resultant low viscosity resin component and the high viscosity resin component

becomes too small and thus the resultant composite staple fibers cannot exhibit a sufficient latent crimping property.

Further, the intrinsic viscosity of the low viscosity resin component must be 0.10 to 0.50 dl/g, preferably 0.2 to 0.40 dl/g, below the intrinsic viscosity of the high viscosity resin component. If the difference in intrinsic viscosity is less than 0.1 dl/g, the resultant composite staple fibers exhibit an insufficient latent crimping property. Also, if the intrinsic viscosity difference is more than 0.5 dl/g, in the melt-spinning procedure, the extruded composite filamentary melt streams bend extremely and adhere to adjacent melt streams and to the spinneret and, thus, are broken. Therefore, the melt-spinning procedure cannot be smoothly carried out.

The mass ratio of the high viscosity resin component to the low viscosity resin component can be appropriately established in consideration of the desired latent crimping property of the target composite staple fibers and the melt-spinnability of the resin components and preferably is in the range of from 30/70 to 70/30, more preferably from 40/60 to 60/40, still more preferably about 50/50.

The hollow composite staple fibers of the present invention each have a hollow part formed in a longitudinal center position of each fiber and filamentarily extending along the longitudinal axis of each fiber. In the hollow composite fiber, the hollow part is advantageous in that when two different resins are melt-extruded through a melt-spinning orifice for a hollow side-by-side or core-in-sheath type composite filament, the hollow part, formed in the longitudinal center portion of the resultant composite filamentary melt stream, causes a high resistance-to-bending force, in the hollow composite filamentary melt streams, to be generated and the stability of the melt-spinning

procedure to be enhanced. Also, in the resultant hollow composite staple fiber, the hollow part causes the rigidity of the fiber to be increased, spiral crimps having an appropriate form to be generated in the composite fibers and the resultant fiber exhibits an increased bulkiness. Also, the nonwoven fabrics and woven and knitted fabrics formed from the hollow composite staple fibers of the present exhibit an excellent bulkiness and elastic recovery.

In the cross-section of the hollow composite staple fiber of the present invention, the hollow part must have a cross-sectional area corresponding to 2 to 15%, preferably 5 to 10% of the total cross-sectional area of the hollow composite fiber. If the proportion (%) of the cross-sectional area of the hollow part is less than 2%, the hollow composite filamentary melt streams extruded in the melt-spinning procedure is caused to bend and the stability of the melt-spinning procedure decreases. Also, small crimps are generated on the resultant hollow composite fibers and thus the resultant fibers cannot have a sufficient bulkiness. Also, if the proportion of the cross-sectional area of the hollow part is more than 15%, the bonding area, of the two resin components in the resultant each hollow composite fiber, becomes too small and thus the latent crimping property of the resultant hollow composite fiber is insufficient.

In the production of the hollow composite staple fiber of the present invention, the proportion of the cross-sectional area of the hollow part to the total cross-sectional area of the hollow composite staple fiber can be easily controlled to 2 to 15% by appropriately controlling the form and size of the orifices of the melt-spinneret, the temperature of the resin melt, and the cooling air flow rate in the melt-spinning procedure.

In the hollow composite staple fiber of the present invention, the hollow part is preferably located in one of the high viscosity polyester resin component and the

low viscosity polyester resin component. In an example, the hollow composite staple fiber has a side-by-side structure, and in the cross-sectional profile of the hollow composites staple fiber, one of the high viscosity and low viscosity resin components occupies a half or more of the cross-sectional area of the hollow composite fiber. Usually, the hollow part is preferably formed within a part comprising the high viscosity resin component.

Fig. 1 shows a cross-sectional profile of an example of the side-by-side type polytrimethylene terephthalate hollow composite fibers of the present invention. In Fig. 1, a hollow composite fiber having a circular cross-sectional profile is constituted from (1) a larger side part 2 comprising a high viscosity resin component, in which part 2 a hollow part 4 having a circular cross-sectional profile is formed, and (2) a smaller side part 3 comprising a low viscosity resin component and conjugated with the larger side part 2 in a side-by-side arrangement.

Fig. 2 shows a cross-sectional profile of another example of the side-by-side type polytrimethylene terephthalate hollow composite fibers of the present invention. In Fig. 2, a hollow composite fiber 1 having a quadrilateral cross-sectional profile and a hollow part 4 is constituted from a right side part 2 and a left side part 3. The hollow part 4 is formed between the right and left side parts 2 and 3, and the right and left side parts 3 and 4 are connected to each other at portions above and below the hollow part 4.

In another example, the hollow composite fiber has an eccentric core-in-sheath structure, and the hollow part is located only in one of the eccentric core part and the sheath part and, preferably, is in the core part.

Fig. 3 shows a cross-sectional profile of still another example of the polytrimethylene terephthalate hollow composite fibers of the present invention having

an eccentric core-in-sheath structure. In Fig. 3, an eccentric core-in-sheath type hollow composite fiber 1 is constituted from a sheath part 2 formed from a low viscosity resin component and having a circular cross-section, and a core part 3 formed from a high viscosity resin component eccentrically arranged in the sheath part 3, having an oval cross-sectional profile, containing a hollow part 4 formed in the core part 3 and having an oval cross-sectional profile.

Fig. 4 shows a cross-sectional profile of a further example of the polytrimethylene terephthalate hollow composite fibers having an eccentric core-in-sheath structure. In Fig. 4, the hollow composite fiber 1 is constituted from a sheath part 2 comprising a low viscosity resin component and having a circular cross-sectional profile and an eccentric core part 3 comprising a high viscosity resin component, arranged in the sheath part 2, having an oval cross-sectional profile and containing a hollow part 4 formed in the core part 3 and having an about triangular cross-sectional profile.

In the above-mentioned examples, the resultant hollow composite fibers are advantageous in that when the latent crimping property of the resultant hollow composite fibers is actualized, the resultant crimps exhibit a large loop form.

In the hollow composite staple fibers of the present invention, there is no limitation to the cross-sectional profiles of the individual fibers and to the cross-sectional forms of the individual hollow parts.

The cross-sectional profiles of the individual fibers and the hollow parts include circular, triangular, flat, multi-lobate and multi-hollow forms, and can be established from various profiles in response to the use and the purpose of the fibers.

The hollow composite staple fibers of the present invention preferably have an individual fiber thickness of 1 to 5 dtex, more preferably 1.5 to 3 dtex. Also, the

hollow composite staple fibers of the present invention preferably have a fiber length of 3 to 150 mm, more preferably about 30 to about 70 mm.

The hollow composite staple fibers of the present invention must have an average web shrinkage of 30 to 70%, preferably 40 to 60%. The average web shrinkage is determined by such a measurement that the hollow composite staple fibers having a fiber length of 51 mm are formed into a web having a basis mass of 30 g/m² by a roller carding machine, a plurality of specimens having dimensions of 20 cm × 20 cm are prepared from the web, the specimens are heat-treated in a hot air circulation dryer at a temperature of 120°C for 10 minutes, to allow the specimens to freely shrink, the web area thermal shrinkages of the specimens are determined in accordance with the equation (1):

$$\text{Web area thermal shrinkage (\%)} = [(A - B)/A] \times 100 \qquad (1)$$

wherein A represents of an area of the specimen before the heat-treatment and B represents an area of the specimen after the heat treatment, and an average of the resultant web area thermal shrinkages of the specimens is calculated.

The average web shrinkage is an index of the latent crimping property of the hollow composite staple fibers. When the average web shrinkage is in the range of from 30 to 70%, the resultant hollow composite staple fibers enable the resultant woven, knitted and nonwoven fabrics therefrom to exhibit sufficient bulkiness and stretchability. If the average web shrinkage is more than 70%, the resultant crimped composite staple fibers have a plurality of small spiral crimps and thus exhibit an insufficient bulkiness and a hard hand, while the stretchability of the fibers is high. Also, in this case, when the mechanically crimped hollow composite staple fibers are subjected to a spinning procedure, the

latent crimps are actualized in, for example, a carding step, and, thus, difficulty in processing occurs. Also, if the average web shrinkage is less than 30%, the latent crimps cannot be sufficiently actualized and the resultant composite staple fibers exhibit an insufficient stretchability.

The average web shrinkage of the hollow composite staple fibers of the present invention can be controlled to 30 to 70% by appropriately controlling the draw ratio and temperature of the drawing procedure applied to the fibers and the proportion of the cross-sectional area of the hollow parts to the total cross-sectional area of the hollow composite fibers, in consideration of the intrinsic viscosities of the polyester resin components used for the composite fibers.

The hollow composite fibers of the present invention may be machine-crimped by using a mechanical crimping apparatus and, for example, a stuffing box-type crimper or a gear type crimper. The percentage crimp of the mechanical crimps is preferably 10 to 25%, more preferably 15 to 20%. The percentage crimp of the hollow composite fibers by the machine-crimping procedure can be easily controlled as desired by appropriately controlling the number of crimps and crimping temperature in the machine-crimping procedure. The percentage crimp of the fibers is determined in accordance with JIS L 1015, Test Method for Man-Made Staple Fibers, 8.12.2.

The hollow composite staple fibers of the present invention can be produced by the process of the present invention comprising the steps of:

melt-spinning two polytrimethylene terephthalate resins, different in intrinsic viscosity from each other, through a hollow side-by-side or core-in-sheath type composite filament-forming spinneret, to provide undrawn hollow composite filaments;

drawing, in two stages, the undrawn hollow composite filaments at a total draw ratio corresponding

to 60 to 80% of the ultimate elongation of the undrawn hollow composite filament, in such a manner that the drawing temperature is 45 to 60°C at the first stage and then 85 to 120°C at the second stage and the drawing ratio for the second stage is controlled to 0.90 to 1.0 so as to adjust the total draw ratio to as mentioned above;

machine-crimping the drawn hollow composite filaments at a temperature of 50 to 80°C;

heat-treating the crimped hollow composite filaments at a temperature of 80°C or less while allowing the crimped hollow composite filament to relax; and

cutting the heat-treated hollow composite filaments to provide hollow composite staple fibers.

In the process of the present invention, the drawing temperature at the first stage is in the range of from 45 to 60°C, preferably 50 to 60°C. If the first stage drawing is carried out at a low temperature of less than 45°C, a high drawing force must be applied to the filaments, due to the low plasticity of the filaments at the low temperature and, thus, the filaments are frequently broken during the drawing procedure. Also, if the drawing temperature at the first stage is more than 60°C, the degree of crystallization of the filaments increases and thus the filaments become fragile and frequently broken.

The drawing temperature and the draw ratio at the second stage influence on the latent crimping property of the resultant drawn filaments and must be adjusted respectively in the ranges of from 85 to 120°C, preferably 90 to 110°C and in the range of from 0.9 to 1.0, preferably 0.92 to 0.98. If the drawing temperature at the second stage is less than 85°C, the latent crimping property of the resultant drawn staple fibers is easily actualized by a mechanical procedure. For

example, when the resultant hollow composite staple fibers are passed through a carding procedure in a spinning process or nonwoven fabric-production process, the latent crimps are actualized to such an excessive extent that defects, for example, neps or holes, are formed in the resultant web. Also, if the drawing temperature at the second stage is more than 120°C, the resultant staple fibers exhibit a decreased latent crimping property. If the drawing procedure at the second stage is carried out at a draw ratio of more than 1.0, the resultant staple fibers are imparted with a plurality of spiral crimps when they are subjected to a machine crimping procedure, the resultant crimped staple fibers which the spiral crimps a difficult to smoothly pass through the carding procedure. In the drawing procedure at the second stage, a heat treatment of the fibers at a fixed fiber length or under a restriction to shrinkage must be applied to the first drawn filaments. If the draw ratio is less than 0.90, the filaments are excessively heat-set and thus the resultant staple fibers exhibit a deteriorated latent crimping property.

In the process of the present invention the total draw ratio in % at the first and second drawing stages must be controlled to an extent corresponding to 60 to 80%, preferably 65 to 75%, of the ultimate elongation of the undrawn hollow composite filaments. If the total draw ratio is less than 60%, the resultant staple fibers exhibit an insufficient latent crimping property. Also, the total draw ratio is more than 80%, the filaments are frequently broken in the drawing step and thus the drawn filaments are difficult to be smoothly produced.

In the process of the present invention, the drawn hollow composite filaments are machine-crimped by using a machine-crimping apparatus and, for example, stuffing box-type crimper or a gear crimper. The machine-crimping procedure is carried out at a crimping temperature of 50

to 80°C, preferably 60 to 70°C.

If the machine-crimping temperature is less than 50°C, the resultant crimped filaments exhibit insufficient percentage crimp. Also, if the machine-crimping temperature is more than 80°C, the latent crimps, which should be kept non-actualized, are undesirably actualized during the machine-crimping procedure, and the actualized spiral crimps cause the resultant hollow composite staple fibers to exhibit a degraded carding machine-passing property. The machine-crimping procedure is preferably controlled to such an extent that the resultant machine-crimped filaments have a number of crimps of 10 to 15 crimps/25 mm, to impart a satisfactory carding machine-passing property to the resultant staple fibers.

After the machine-crimping step, the machine-crimped hollow composite filaments are heat-treated at a temperature or 80°C or/less preferably 40 to 50°C, while allowing the crimped hollow composite filaments to relax. If the heat-treating and relaxing temperature is higher than 80°C, the latent spiral crimps are undesirably actualized. There is no lower limit to the temperature at which the heat-treatment is carried out while allowing the crimped hollow filaments to relax.

Usually, the filaments before the machine-crimping procedure are oiled with an aqueous emulsion of a finish-oiling agent and, thus, the heat-treatment should be effected at a temperature high enough to dry the filaments by evaporating the water on the filaments. Thus, the heat-treatment is preferably carried out at a temperature of 40°C or more. The simultaneous heat-treating and relaxing procedure is preferably carried out for a time of 30 to 60 minutes.

After the simultaneous heat-treating and relaxing procedure is completed, the resultant hollow composite

filaments are cut by using a tow-cutting machine, for example, a grugru cutter and a rotary cutter, to provide hollow composite staple fibers having a desired fiber length of, preferably, 3 to 15 mm.

EXAMPLES

The present invention will be further explained by the following examples.

In the examples and comparative examples, the following measurements were carried out.

(1) Intrinsic viscosity [η]

The intrinsic viscosity of polyester resin was determined in a solution of the polyester resin in a solvent consisting of orthochlorophenol at a temperature of 35°C by using an Ubbelohde viscometer.

(2) Velocity of cooling air blast

A velocity of cooling air blast having a temperature of 25°C and a humidity of 65% applied to filamentary streams of extruded polyester resin melt in the melt-spinning apparatus at right angles to the travelling direction of the filamentary streams, to cool and solidify the filamentary streams, was measured by a wind velocity meter.

(3) Cross-sectional proportion of hollow part in hollow composite fiber

In a cross-sectional profile of a hollow composite fiber, a proportion of the area of a hollow part of the hollow composite fiber to the total area of the fiber was measured.

(4) Ultimate elongation of undrawn filaments

The ultimate elongation of an undrawn hollow composite filament tow was measured by a constant elongation speed type tensile tester, at a distance between grippers of 10 cm at a tensile speed of 100 cm/mm, in accordance with JIS L 1013 - 1999.

(5) Percentage crimp

The percentage crimp of a fiber was determined

in accordance with JIS L 1015 - 1999.

(6) Stability of melt-spinning procedure

The numbers of breakages of the undrawn filaments generated in the melt-spinning procedure, per melt-spinneret, per 8 hours, except for breakages of the filaments generated due to human-originated cause and mechanical cause, was counted, to classify the stability of the melt-spinning procedure based on the breakage number, as follows.

Stability	Number of filament tow breakages
Excellent	0
Good	1 to 2/8 hour·spinneret
Bad	3 or more/8 hour·spinneret

(7) Web area thermal shrinkage (%)

The hollow composite staple fibers having a fiber length 51 mm were formed into a web having a basis mass of 30 g/m^2 by using a roller carding machine; a plurality of specimens having dimensions of 20 cm × 20 cm were prepared from the web; each specimen was heat-treated in a hot air circulation dryer at a temperature of 120°C for 10 minutes to allow the specimens to freely shrink; the web area thermal shrinkages of the specimen were determined in accordance with the equation (1):

$$\text{Web area thermal shrinkage (\%)} = [(A - B)/A] \times 100 \qquad (1)$$

wherein A represents an area of the specimen before the heat-treatment and B represents an area of the specimen after the heat-treatment; and an average of the resultant web area thermal shrinkages of the specimens was calculated.

(8) Elastic recovery and bulkiness of nonwoven fabric made from the hollow composite staple fibers.

The hollow composite staple fibers, having a fiber length of 51 mm, were formed into nonwoven webs by using a roller carding machine; a plurality of the resultant webs were laminated to each other; the

laminated webs were needle-punched to provide a nonwoven fabric having a basis mass of about 50 g/m^2; the nonwoven fabric was heat-treated in an oven at a temperature of 120°C for 10 minutes; the bulkiness of the nonwoven fabric was measured in accordance with JIS L-1908; then a plurality of specimens in the form of a tape having a width of 25 mm were prepared from the nonwoven fabric, and each subjected to a measurement of ultimate elongation in accordance with JIS L-1908-1999, at a distance between a pair of grippers of 100 mm and at a tensile speed of 100 mm/min; and from the resultant data, the elastic recovery of the specimens were calculated in accordance with the equation (2):

$$\text{Elastic recovery (\%)} = (E_B - E_C)/E_B \times 100$$

wherein E_B represents an elongation (%) corresponding to 80% of the ultimate elongation of the specimen, and E_C represents an elongation (%) of the specimen after the specimen was elongated until the elongation of the specimen reached the elongation E_B, then the specimen was released from the tension applied thereto and left to stand for one minute, based on the original length of the specimen.

(9) General evaluation

The general evaluation of the hollow composite staple fibers was carried out on the basis of the stability of the melt spinning procedure, the bulkiness of the nonwoven fabric and the elastic recovery of the nonwoven fabric. The evaluation results were represented in the following two classes.

General evaluation	Performance
Good	No breakage of filament tow occurs in 8 hour melt spinning procedure per melt-spinneret, the bulkiness of the nonwoven fabric is 15 cm^3/g or more, and

	the elastic recovery of the nonwoven fabric is 80% or more.
Bad	At least one of the above-mentioned items does not reach the levels mentioned above.

<u>Examples 1 and 2 and Comparative Examples 1 to 6</u>

In each of Examples 1 and 2 and Comparative Examples 1 to 6, the high viscosity polytrimethylene terephthalate resin component (A) having the intrinsic viscosity and the low viscosity polytrimethylene terephthalate resin component (B) as shown in Table 1 or 2 were subjected to a melt-spinning procedure using a melt-spinneret for hollow eccentric core-in-sheath type composite filaments having 1000 extruding orifices. In each orifice for the hollow composite fiber, the diameter of a circular slit for forming the hollow part in the hollow composite fiber (PCD) was as shown in Table 1 or 2.

In the melt-spinning procedure, the high and low viscosity polyester resin components (A) and (B) were used in a mass ratio A/B of 50/50, melted at the temperatures as shown in Table 1 or 2 in the range of from 245 to 290°C, and melt-extruded at a total extruding rate of 690 g/mm. The extruded melt filamentary streams were cooled and solidified by applying a cooling air blast to the streams at the blast speed as shown in Table 2, and the resultant undrawn hollow composite filament bundle was taken up and wound around a winding roll at a taking-up speed of 1,300 m/min. The melt-spinning procedure was continuously carried out over a period of 8 hours, to check the stability of the melt-spinning procedure, by counting the number of breakages of the filaments.

The resultant undrawn hollow composite filament bundle was drawn in two stages under the drawing

conditions, namely the drawing temperatures and the draw ratios at the first and second drawing stages and the total draw ratio, as shown in Table 1 or 2. Then the drawn hollow composite filament bundle was subjected to a machine-crimping procedure at a temperature of 75°C to impart mechanical crimps, at the percentage crimp shown in Table 1 or 2, to the individual filaments. The machine-crimped hollow composite filament bundle was heat treated at a temperature of 55°C for 30 minutes while relaxing the filaments. The relaxed and heat-treated filaments were cut at a fiber length of 51 mm to prepare hollow composite staple fibers.

The resultant staple fibers were formed into a web by using a caring machine, and the web area thermal shrinkage was measured. The result is shown in Table 1 or 2.

The web was subjected to the measurements of elastic recovery and bulkiness of the corresponding nonwoven fabric as mentioned above. The results are shown in Table 1 or 2.

In comparative Example 3, the melt-spinning procedure could not be smoothly carried out due to frequent breakages of the extruded filaments and thus the desired undrawn filaments could not be obtained.

Comparative Example 7

In Comparative Example 7, the same procedures and measurements as in Example 1 were carried out, except that, in the melt-extruding orifices, the PCD was changed to 2.0 mm as shown in Table 2.

The measurement results are shown in Table 2.

Comparative Example 8

In Comparative Example 8, the same procedures as in Example 1 were carried out, except that the melt-extruding orifices had no hollow-forming slit, the velocity of the cooling air blast was changed from 0.6 m/sec to 0.7 m/sec, and the resultant composite

fibers had no hollow.

The measurement results are shown in Table 2.

Table 1

Item \ Example No.			Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3
High viscosity resin component	Intrinsic viscosity	(dl/g)	1.30	0.50	1.45	0.45	1.30
	Melt temperature	(°C)	280	255	290	250	280
Low viscosity resin component	Intrinsic viscosity	(dl/g)	0.90	0.40	1.10	0.35	0.75
	Melt temperature	(°C)	250	245	255	245	250
Difference in intrinsic viscosity between high and low viscosity resin components		(dl/g)	0.40	0.10	0.35	0.10	0.55
Type of melt extruding orifice			Hollow	Hollow	Hollow	Hollow	Hollow
Cooling air blast velocity		(m/s)	0.6	0.6	0.6	0.6	0.6
Ultimate draw ratio of undrawn filament			2.8	3.2	2.5	3.2	-
Diament of circular slit in orifice for hollow part in hollow composite fiber		(mmϕ)	0.7	0.7	0.7	0.7	0.7
First drawing stage	Temperature	(°C)	53	53	53	53	
	Draw ratio		2.0	2.2	1.8	2.2	
Second drawing stage	Temperature	(°C)	110	95	110	95	
	Draw ratio		0.95	0.95	0.95	0.95	
Total draw ratio			1.9	2.1	1.7	2.1	-
Crimping temperature		(°C)	75	75	75	75	
Relax, heat treatment temperature		(°C)	55	55	55	55	
Proportion of hollow part to total cross-sectional area		(%)	7	2	12	3	5
Percentage crimp		(%)	15	18	15	17	
Stability of melt-spinning procedure			Excellent	Excellent	Bad	Good	Bad
Web area thermal shrinkage		(%)	48	36	42	23	-
Bulk density of nonwoven fabric		(cm^3/g)	23	24	22	29	
Ultimate elongation of nonwoven fabric		(%)	205	189	199	148	
Elastic recovery of nonwoven fabric		(%)	93	89	92	74	
General evaluation			Good	Good	Bad	Bad	Bad

Table 2

Item		Example No.	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8
High viscosity resin component	Intrinsic viscosity	(dl/g)	1.30	1.30	1.30	1.30	1.30
	Melt temperature	(°C)	280	280	280	280	280
Low viscosity resin component	Intrinsic viscosity	(dl/g)	1.25	0.90	0.90	0.90	0.90
	Melt temperature	(°C)	275	250	250	250	250
Difference in intrinsic viscosity between high and low viscosity resin components		(dl/g)	0.05	0.40	0.40	0.40	0.40
Type of melt extruding orifice			Hollow	Hollow	Hollow	Hollow	Solid
Cooling air blast velocity		(m/s)	0.6	0.6	0.6	1.0	0.7
Ultimate draw ratio of undrawn filament			2.5	2.8	2.8	2.8	2.9
Diament of circular slit in orifice for hollow part in hollow composite fiber		(mmϕ)	0.7	0.7	0.7	2.0	-
First drawing stage	Temperature	(°C)	53	53	53	53	53
	Draw ratio		1.8	2.0	1.9	2.0	2.0
Second drawing stage	Temperature	(°C)	95	110	95	110	110
	Draw ratio		0.95	0.95	1.05	0.95	0.95
Total draw ratio			1.7	1.9	2.0	1.9	1.9
Crimping temperature		(°C)	75	75	75	75	75
Relax, heat treatment temperature		(°C)	55	55	55	55	55
Proportion of hollow part to total cross-sectional area		(%)	10	1.5	8	17	-
Percentage crimp		(%)	13	20	23	14	22
Stability of melt-spinning procedure			Excellent	Good	Good	Good	Bad
Web area thermal shrinkage		(%)	23	66	74	27	68
Bulk density of nonwoven fabric		(cm^3/g)	32	17	14	30	15
Ultimate elongation of nonwoven fabric		(%)	138	208	205	168	199
Elastic recovery of nonwoven fabric		(%)	69	92	89	74	88
General evaluation			Bad	Bad	Bad	Bad	Bad

INDUSTRIAL APPLICABILITY OF THE INVENTION

The polytrimethylene terephthalate hollow composite stable fibers of the present invention have a high latent crimping property and, thus, exhibit excellent bulkiness and elastic recovery. Therefore, they are useful for nonwoven fabrics, woven or knitted fabrics and cushioning materials.